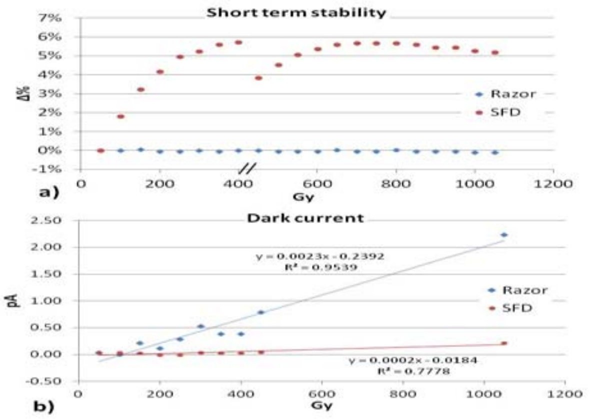
Purpose/Objective: Stereotactic radiotherapy requires suitable detectors to determine the delivered dose with high accuracy. Aim of this study was to determine the potentialities of an unshielded silicon diode prototype for dose measurements in radiation therapy small photon beams under flattening filter free (FFF) beams.

Materials and Methods: A prototype of a new designed stereotactic diode from IBA, named Razor, was evaluated in comparison with previously available SFD diode and the PFD detectors from IBA It is made with a n-type implant in p-type silicon. Active area has 0.6mm diameter and the active depth is about 20μm. The stability of the detector response in terms of dose, dose rate, and dose per pulse were evaluated. Dark current as function of received dose was also evaluated. Different square field sizes ranging from 0.8 to 5 cm were evaluated by means of percentage depth dose curves (PDDs), axial beam profiles, and output factors.

Results:



Razor's short term stability showed a variation below ±0.1% for a 1.2 kGy single-session delivery, much better than the old SFD (Figure 1a). The Razor response showed a deviation from linearity of less than ±1% in the 0.05–30 Gy range and a dose rate dependence below ±0.5% in the 4–24 Gy/min range. The dose per pulse dependence, evaluated in the 0.08-0.21 cGy/pulse range, resulted below±0.8%. The temperature dependence was investigated as well, though in a small range (20-30°C), and a 0.05%/°C variation was found. A higher increase of the dark current with increasing dose was observed too for the Razor with values of 0.0025pA/Gy against the 0.0002pA/Gy of the old SFD (Figure 1b). This can be addressed to an increasing concentration of the recombination centers due to radiation damage and can be practically solved by resetting the background before every acquisition.

Conclusions: The new evaluated detector has interesting characteristics, especially in terms of spatial resolution, for small field measurements with improved stability (up to 1.2 kGy) compared to the reference stereotactic diode. These features make the Razor detector a good candidate for small field dosimetry in advanced radiation therapy techniques.

PO-0832

Ion recombination correction for a parallel-plate ionization chamber in a carbon ion beam

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Purpose/Objective: Due to the development and increased use of hadrontherapy, reference dosimetry of charged particle beam, and in particular the absorbed dose to water measurement using ionization chambers, has to be improved to decrease the uncertainty of the treatment and improve its consistency. Ion recombination is one of the corrections that need to be applied to an ionization chamber measurement that is potentially much larger in a carbon ion beam as compared to conventional photon or electron beams. This work aims at measuring the ion recombination correction (k_s) for parallel-plate ionization chambers in a carbon ion beam from a slow cycle synchrotron.

Materials and Methods: Measurements were performed for two IBA Roos chambers (PPC40) irradiated by a 10 cm diameter field at three dose rates, six polarizing voltages and two orientations of the chambers. Two different measurement positions and energies were used: the middle of the 6 cm spread-out Bragg peak (SOBP) in a 290 MeV/n energy-modulated carbon ion beam and the plateau of a 135 MeV/n non-modulated carbon ion beam. To achieve a very good correlation between the ionization in the test chamber and that in the monitor, both chambers were placed face-to-face in a PMMA phantom, one serving as the monitor chamber.

Results: The ion recombination mechanism depends on the LET of the beam. Using high-LET beams, we observed a near linearity of the plot (1/Q) versus (1/V) confirming that the mechanism is dominated by initial recombination. Consequently, in this preliminary analysis, we neglected volume recombination.

For the 290 MeV/n modulated carbon ion beam, k_s was found to be 1.0098 with a standard uncertainty u_C of 0.10% and 1.0099 (u_C = 0.15%) for the two chambers, respectively. For the 135 MeV/n non-modulated carbon ion beam, k_s was found to be 1.0064 (u_C = 0.13%) and 1.0054 (u_C = 0.14%) for the two chambers, respectively.

As expected by Jaffé's theory the initial ion recombination depends on the angle between the ion path and the electric field. With an angle of 45 degrees, k_s was found to decrease strongly. In this case, for the two chambers, we obtained 1.0029 (u_C = 0.17%) and 1.0011 (u_C = 0.16%) for the 290 MeV/n modulated beam and 1.0018 (u_C = 0.16%) and 1.0023 (u_C = 0.16%) for the 135 MeV/n non-modulated beam.

Conclusions: We have determined ion recombination correction factors for two parallel-plate ionization chambers in a carbon ion beam. Due to the high LET of the beams, the mechanism is dominated by initial recombination consistent with other findings in the literature. The values are, however, somewhat lower than other values reported in the literature which may warrant further investigations in beams with different pulse shapes. Significant differences in recombination correction factors appear depending on the orientation of the chamber which is also consistent with other observations in the literature and with the theory of Jaffé.

PO-0833

CHO cell depth-survival distributions after different configurations of contralateral carbon beams

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Purpose/Objective: Contralateral ion beams, both with spread out Bragg peaks (SOBP), will yield a more uniform dose distribution over the target region than that from a single-port SOBP irradiation. We may achieve this either by superposing two contralateral beams, each with a 'flat' SOBP dose distribution (case A), or by applying two 'ramped' SOBP beams (case B). For these two carbon beam configurations we compared the depth distributions of dose, survival, RBE, dose-averaged energy and dose-averaged LET over the target region, against another calculation where we obtained a desired uniform level of survival over the target region directly using our other optimisation algorithm (case C).

Materials and Methods: We applied a numerical algorithm to optimise the entrance spectra of a composition of pristine carbon ion beams which delivers a desired dose-depth profile over a given range by spreading out the Bragg peak. The physical beam transport model was generated using the SHIELD-HIT10A Monte-Carlo code. A multi-dimensional interpolation algorithm was used to calculate at given beam depths the cumulative energy-fluence spectra for primary and secondary ions in the optimised beam composition, as required by the mixed-field calculation of Katz's cellular Track Structure Theory (TST) which then predicts the resulting depth-survival profile. The depth-dose profile is optimised over a given depth range using the L-BFGS-B algorithm, with parallel processing support. Another optimisation algorithm incorporating the formulae of Katz's TST, is able to yield a desired survival-depth profile directly. Our 1-dimensional irradiation geometry consisted of a 4 cm slab of 'target volume' surrounded by 8 cm slabs of 'healthy tissue' both composed of water and of CHO cells represented by Katz's TST cellular parameters (m = 2.31, d0 = 1.691 Gy, sigma0 = 5.967e-11 m^2, kappa = 1692.8). The desired dose over the target volume was 3 Gy and the survival level 20%.

Results: With respect to dose-depth distributions, we found that the '2 flat dose' (case A) gave the best sparing of healthy tissue, compared with '2 ramp dose' (case B) and 'flat survival' (case C). However, case A gave a highly non-uniform survival distribution over the target region ('underkill' in the central region and 'overkill' at its borders), unlike cases B and C (uniform survival distribution over the target region). The '2 flat dose' (case A) gave the highest non-uniformity of dose-averaged energy and dose-averaged LET distributions over the target region.

Conclusions: Our 1-dimensional kernel of a carbon beam therapy planning system, based on a beam transport model, Katz's Track Structure Theory with in vitro cell survival parameters, and efficient optimisation algorithms, is able to yield quantitative predictions of various beam configurations and irradiation strategies relevant to therapy planning using carbon beams.

Poster: Physics track: Dose measurements

PO-0834

Derivation of a universal dataset for commissioning of an EPID-based dosimetry system

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Purpose/Objective: Commissioning an EPID for dosimetry purposes requires a large number of measurements, which is time-consuming and cumbersome. In order to decrease the commissioning time, the use of a universal dataset would be advantageous. In this study the derivation and feasibility of such a universal dataset is described.

Materials and Methods: Measurements were performed on 22 Elekta linac/photon beam energy combinations at 10 different sites in 6 countries, all equipped with aSi iViewGT EPID systems (see table). A single set of equipment, consisting of an electrometer, two types of IC, mini-phantoms and a slab phantom, was sent to each site prior to the measurements.

Table 1. Overview of the Elekta linac/photon beam energy combinations investigated in this study

Site	Energy	Head Type
Denmark: OUH, Odense	18MV	MLCi, Agility
France: Claude Bernard, Metz	6MV	BeamModulator
Netherlands: AMC Almere	6MV, 10MV	MLCi
Netherlands: AMC Amsterdam	6MV, 10MV	Agility
Netherlands: AVL Amsterdam	6MV, 10MV, 6MV FFF, 10MV FFF	MLCi, Agility
Portugal: Champalimaud, Lisbon	6MV, 10MV	MLCi
United Kingdom: St James' Leeds	6MV, 10MV	Agility
United Kingdom: RMH, Sutton	10MV, 15MV	BeamModulator
United Kingdom: Elekta, Crawley	6MV FFF, 6MV FFF	Agility
USA: Univ. Washington, Seattle	6MV, 10MV, 18MV	MLCi, BeamModulator

IC measurements were performed using different combinations of phantom thicknesses and field sizes to obtain the dosimetric characteristics of the linac. Additionally, IC measurements in a mini-phantom were performed at EPID level. EPID images were then acquired for all thickness/field size combinations. For the full commissioning in total, 45 IC measurements and 50 EPID images were required per linac/energy combination, which takes approximately 4 hours.

From this large dataset a universal dataset has to be derived which should then be combined with as few as possible linac specific measurements to complete the modeling. The accuracy of using such a simplified procedure was tested by comparing the 2D dose distribution in a polystyrene phantom, reconstructed from the EPID measurements and the universal